

Effects of composted swine manure on weed seedbank

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Abstract

Deep-bedded hoop structures where pigs are raised on a thick layer of crop residues represent a promising swine production system that allows recycling of farm waste products. A field study was conducted to evaluate the impact of swine compost on weed seedbank abundance, seed persistence, and seedling emergence. Experiments were conducted from 1998 to 2001 in a chisel plow corn–soybean–winter wheat rotation. In the fall of 1998, and before compost application, weed seedbank abundance, species composition, and viability were characterized. Annual weed seed inputs attributed to compost were assessed between 1998 and 2000 and seedbanks were characterized again in the fall of 2001.

Giant foxtail, common lambsquarters, common waterhemp, and Pennsylvania smartweed comprised 99.5 and 80.7% of seeds detected in the seedbank and compost, respectively. Between 1 ± 1 and 169 ± 48 weed seeds m^{-2} of soil surface (mean \pm S.E.M.) were incorporated through compost amendments, the mean number of viable seeds in the compost being less than 8 seeds m^{-2} . Weed seed density in the seedbank ranged from 0 ± 0 to $26,662 \pm 8683$ seeds m^{-2} to a depth of 10 cm. Compost did not modify seed abundance, but there was a species-specific response to year of study and crop sequence. Weed seed longevity and seedling emergence were not affected by compost, but more seeds were recovered with a higher viability in 2000 than in 2001. These results indicate that use of composted swine manure represents a small risk to directly increase weed seed abundance in the seedbank.

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1. Introduction

Integrated farming systems require adequate weed management programs embedded within the agricultural production framework. One approach recently developed for swine production is the use of deep-

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bedded hoop structures in which animals are raised in a thick layer of corn stalks or small grain straw. The bedding absorbs dung and urine and allows swine waste products to be handled as solids with reduced air and water contamination risks (Honeyman et al., 1999; Honeyman and Kent, 2001). Composting of the bedding/manure mixture occurs within the hoop structure before hogs are removed and continues afterwards when the mixture is stored in piles prior to field application (Richard et al., 1998). Composted swine manure produced in deep-bedded hoop structures represents a concentrated source of nutrients that can beneficially modify soil chemical characteristics (Richard and Smits, 1999; Loecke et al., 2004).

Animal manures could impact weed seedbank in several ways. If not properly composted and stored, they can serve as vectors of viable weed seeds into the seedbank (Tompkins et al., 1998; Mt. Pleasant and Schlather, 1994). Compost can release phytotoxic compounds that can influence weed germination (Baskin and Baskin, 1998; Maramba and Ando, 1992; Roe et al., 1993; Ligneau and Watt, 1995; Ozores-Hampton et al., 1999) or reduce the seedbank due of soil-borne pathogens (Kennedy and Kremer, 1996; Fennimore and Jackson, 2003). Amendments can also alter both the competitive ability and seed production of weeds (Liebman et al., 2004; Menalled et al., 2004).

This study examines the impact that composted swine manure has on weed seedbank. Specifically, it evaluates if seed abundance, viability, and emergence dynamics are modified by composted swine manure used in relation to a corn (*Zea mays* L.)–soybean [*Glycine max* (L.) Merr]–winter wheat (*Triticum aestivum* L.) rotation within a chisel plow system.

2. Methods

The study was conducted at the Iowa State University Agronomy and Agricultural Engineering Research Center, Boone, IA, USA (42°01'N, 93°45'W) on a Canisteo silty clay loam (fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquolls) and Clarion loam (fine-loamy, mixed, superactive, mesic Typic Hapludolls). The site was under continuous corn production from 1987 to 1996. In 1988, the site was divided into 12 plots (7.6 m × 27.2 m) following a randomized complete block design with

four replications. Plots were subjected to one of three tillage regimes (fall moldboard plow, fall chisel plow, or no tillage). In 1997, the entire site was planted to soybean and beginning in October 1997, a 3 year corn–soybean–winter wheat rotation was initiated, with each crop present each year in the three tillage systems.

This study considered chisel plow plots only, from fall 1998 to fall 2001. During this study, corn var. 'Pioneer 3563' was planted in late April each year at 81,510 seeds ha⁻¹. Glyphosate-tolerant soybean ('Pioneer 92B84') was planted in mid-May at 444,600 seeds ha⁻¹ in 0.76 m rows. Arapahoe wheat was planted in early October at 3.2 million seeds ha⁻¹ in 0.19 m rows. A leguminous cover crop was established in each wheat plot using 20 kg seed ha⁻¹ using 'Bigbee' berseem clover (*Trifolium alexandrinum* L.) (March 1998 and 1999) and 'Cherokee' red clover (*Trifolium pratense* L.) (March 2000 and 2001). All cover crops were killed with glyphosate each fall. Starting in 2002, straw residue was retained after wheat harvest on the amended plots, but was baled and removed from the unamended plots.

Chisel plow depth was 25 cm and was performed with twisted shanks. Spring secondary tillage operations included one early spring disking and one pre-plant field cultivation. In soybean plots, a single postemergence application of 0.9 kg ae ha⁻¹ of glyphosate was conducted. Weeds were controlled in corn plots using a pre-emergence broadcast application of metolachlor [2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)] acetamide. The application rate was 2.24 kg a.i. ha⁻¹ applied in solution with 140.25 L H₂O ha⁻¹. Rotary hoeing and interrow cultivation were performed as needed to remove weeds in the corn and soybean plots. No herbicides were applied to wheat and mowing was used to control weeds after crop harvest.

In 1998, plots were halved to accommodate applications of composted swine manure on 7.6 m × 13.6 m sub-plots. The assignment of the sub-plot treatment was randomized and compost was applied in October 1998, 1999, 2000, and 2001. In 1998–2000, 8 t C ha⁻¹ was applied preceding the corn and soybean crops (4 t C ha⁻¹ in 2001), i.e. compost rates to achieve the targeted C rate were 61.6, 74.7, 54.1, and 22.3 t dry matter ha⁻¹ in 1998, 1999, 2000, and 2001, respectively. The compost was produced on a commercial farm in 1998 and on the Iowa State

Table 1
Composition of composted swine manure applied to a corn–soybean–wheat rotation in Iowa (USA)

Year	H ₂ O ^a (g kg ⁻¹)	P (g kg ⁻¹)	K (g kg ⁻¹)	C (g kg ⁻¹)	N (g kg ⁻¹)	C:N	NH ₄ -N (μg g ⁻¹)	NO ₃ -N (μg g ⁻¹)
1998	340	^b	^b	114	10.6	10.8	^b	^b
1999	318	5.0	11.2	105	7.6	13.8	84	63
2000	311	7.2	16.1	147	13.0	11.3	339	999
2001	415	6.2	13.7	227	13.9	16.3	103	396

^a Moisture content is presented on a wet weight basis, all other variables are presented on a dry weight basis.

^b Not measured.

University Rhodes Research Farm in 1999–2001. Compost characteristics are listed in Table 1. An assessment of the impact that composted swine manure had on soil chemical characteristics at the study site can be found in Singer et al. (2004). Late spring soil N concentrations were used to determine sidedress application to corn plots in the form of 32% urea using a modified spoke-wheel fertilizer injector. To achieve similar levels of inorganic N available to corn in both treatments, a higher rate of synthetic N was applied in sub-plots not receiving compost than in plots receiving compost (see Singer et al., 2004 for details).

2.1. Compost and seedbank evaluation

Seed inputs through compost application were assessed based on 36 compost samples per replication and year. Samples were thoroughly mixed to obtain six sub-samples of 100 g of compost in 1998 and 1999. In 2000, due to coarser nature of the compost, 50 g sub-samples were obtained. Seeds were extracted from sub-samples using a flotation/centrifugation method (Buhler and Maxwell, 1993), sorted to species, and counted as number of seeds per square metre of soil surface. Seed viability was assessed by direct germination by placing seeds in petri dishes with filter papers embedded with water. Petri dishes were placed for one week in a germination chamber with a photoperiod of 12:12 and temperatures of 30 °C:20 °C (L:D). Viability of non-germinated seeds was tested with the tetrazolium staining test (Moore, 1972).

Field seedbank abundance, composition, and viability were characterized in the fall of 1998, prior to any compost application, and in 2001. Eight soil cores (7 cm diameter, 10 cm depth) were sampled in the central 3.6 m × 9.6 m of each sub-plot following a W-shaped pattern. Cores from each sub-plot were

thoroughly composited and six 100 g sub-samples were obtained. Weed seeds were extracted from soil samples and viability was tested as described above.

2.2. Seed germinability and emergence patterns

Artificial seedbanks were used to determine weed seed longevity and seedling emergence dynamics and were established in each soybean sub-plot on 10 November 1999 and on 10 November 2000. Three 40 cm diameter PVC pipes were pressed into the soil and the upper 5 cm soil in each pipe was removed and thoroughly mixed with 500 yellow foxtail [*Setaria glauca* (L.) Beauv.], 500 common sunflower (*Helianthus annuus* L.), and 500 common waterhemp (*Amaranthus rudis* Sauer) seeds. Seeds and soil were then returned to the pipe. Weed seeds utilized in this study were collected locally and their viability, estimated within one month after burial by pressure test, direct germination, and tetrazolium-staining test, ranged between 95.5 and 100%.

Artificial seedbanks were destructively sampled in early spring, mid-summer, and at the end of the growing season to obtain an estimate of the seedbanks decline over winter, during the period of active germination, and the residual seedbank. At each sampling time, one randomly selected PVC pipe was removed and stored at 0 °C for seed extraction as previously described.

The effect of compost amendment on seedling emergence was evaluated in artificial seedbanks on a weekly basis between 29 March 2000 and 1 August 2000, and between 11 April 2001 and 15 August 2001. Seedlings of *H. annuus* and *A. rudis* were counted and removed when cotyledons were fully expanded and *S. glauca* at the time of first leaf emergence.

Daily air temperature was obtained from a meteorological station located at the study site.

Growing degree day (GDD) values were calculated as the mean of the minimum and maximum temperature minus a base temperature of 10 °C. Accumulated GDD values from the time of artificial seedbank establishment were calculated and used to compare time of seedling emergence between years.

2.3. Statistical analysis

Seed abundance and viability data for the four most prevalent weed species detected were subjected to analysis of variance (ANOVA). The impact of compost application on seedbank abundance and viability was analyzed with a split-split plot ANOVA with crop as a whole plot factor, year of analysis as a split factor, and compost application as a split-split factor. Number of weed seed recovered from artificial seedbanks and viability of recovered seeds were analyzed with a repeated measures ANOVA model, with presence or absence of compost, year of study, and replication as between-subject factors, and time of sampling as a within-subject factor. Weed seedling cumulative emergence was evaluated with a repeated measures ANOVA model with cumulative growing degree-days being the within-subject factor. To reduce the possibility of failing to meet the assumptions of normality and equality in the variance-covariance matrices, the degrees of freedom of the repeated measures *F*-test

were adjusted with the Geisser-Greenhouse correction (Crowder and Hand, 1990).

3. Results

3.1. Weed seeds in compost and seedbank

Four species [giant foxtail (*Setaria faberi* Herm.), common lambsquarters (*Chenopodium album* L.), *A. rudis*, and Pennsylvania smartweed (*Polygonum pensylvanicum* L.) comprised 99.5 and 80.7% of seeds sampled in the seedbank and compost, respectively. Mean (\pm S.E.M.) weed seed inputs into the seedbank through compost amendment ranged from 1 (\pm 1) to 169 (\pm 48) seeds m^{-2} with the smallest addition observed for *P. pensylvanicum* in 2000 and the largest for *A. rudis* in 1998 (Fig. 1). Total *S. faberi* and *A. rudis* seed number in compost was largest in 1998. The mean number of viable weed seeds incorporated into the seedbank via compost application was less than 8 seeds m^{-2} of soil surface except for *A. rudis*. The largest addition of viable seeds through compost was detected in *A. rudis* in 1998 (86 ± 16 seeds m^{-2}).

Weed abundance ranged from 0 (\pm 0) seeds m^{-2} to 26,662 (\pm 8,683) seeds m^{-2} (Fig. 2). Compost application did not influence weed seedbank abundance or viability of any of the four main species studied. Seed

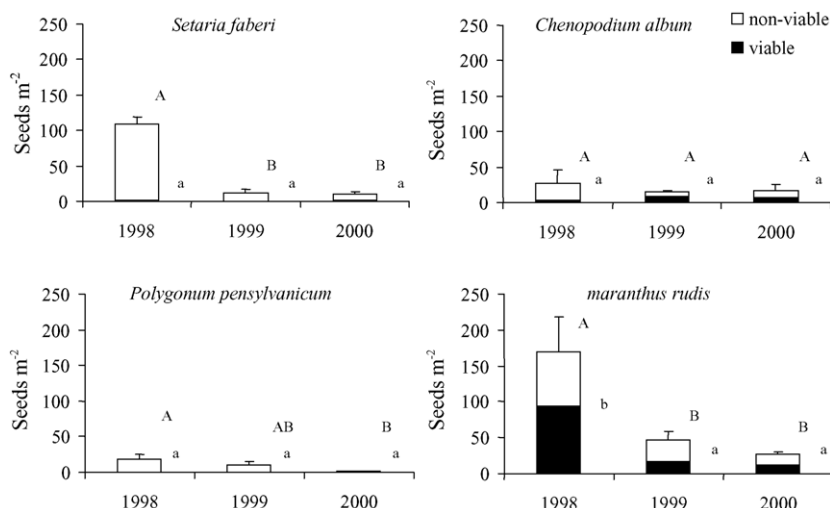


Fig. 1. Mean seed number (\pm S.E.M.) incorporated into the seedbank through compost application. Significant differences based on LS Mean comparisons ($P < 0.05$) indicated by letters: A and B for total seed number; a and b for number of viable seeds.

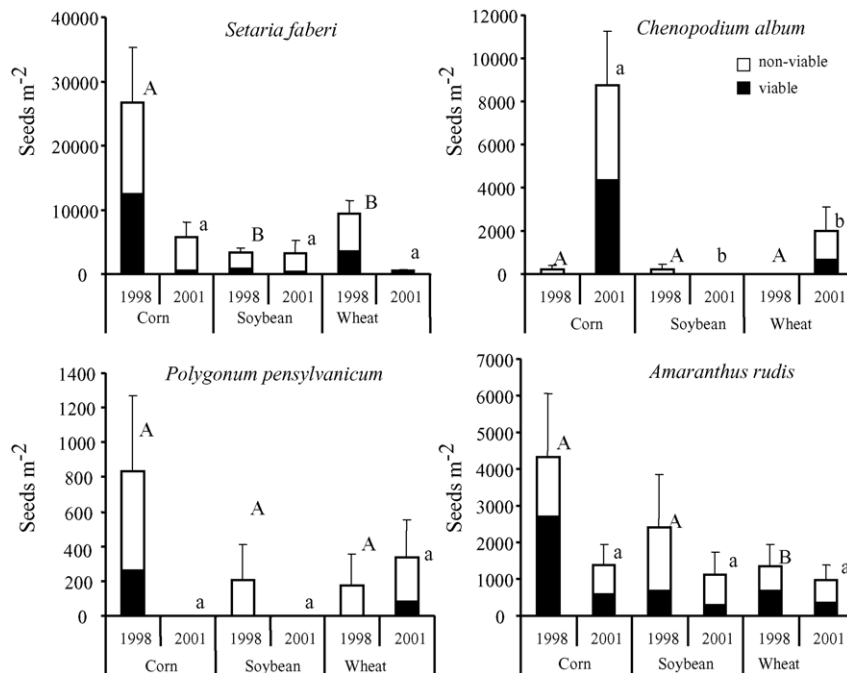


Fig. 2. Mean seed number (\pm S.E.M.) present in the seedbank. Significant differences based on LS Mean comparisons ($P < 0.05$) indicated by letters: A and B for seed number in 1998; a and b for seed number in 2001.

abundance showed a species-specific response to year of study and crop rotation with more *S. faberi* seeds present in corn in 1998 than in wheat or soybean. In 1998 more *A. rudis* were found in corn and soybean than in wheat. In 2001, however, the abundance of these two weed species was similar among the three crops. *Chenopodium album* showed an opposite trend with a similar number of seeds among crops in 1998, but more seeds in corn than in soybean or wheat in 2001. Viability of weed seeds in the soil varied as a function of year of study, crop, and species (Fig. 2).

3.2. Weed seedbank longevity and seedling emergence

Compost did not affect the viability or the number of weed seeds in the artificial seedbanks. More seeds were recovered from artificial seedbanks with higher viability in 2000 than in 2001. In the fall of 2000, 48.1% *A. rudis*, 24.4% *H. annuus*, and 19.6% *S. glauca* were recovered compared to 26.5, 15.1, and 4.8% in fall 2001, respectively. Within each year,

lower numbers were observed in mid-summer and early fall than in early spring.

Environmental factors required for emergence vary from species to species and are mainly affected by temperature, water, and soil physical state (Leblanc et al., 1999). Although the influence of nutrient availability, including nitrogen, on weed growth has been assessed (Salas et al., 1997; Harbur and Owen, 2004) the extent to which they could modify weed emergence is largely unknown. Compost did not modify cumulative emergence of *S. glauca* and *A. rudis*. More seedlings emerged in 2001 than in 2000 and accumulated GDD required for initial emergence was lower for *H. annuus* than *S. glauca*. In 2000, total cumulative emergence of *H. annuus*, *S. glauca*, and *A. rudis*, was 36.7, 20.2, and 2.0, respectively, and 60.3, 30.2, and 10.0% in 2001. After tallying seedling emergence and seed recovery, a considerable fraction of seeds was not recovered from seedbanks within a year of establishment. In fall 2000, 41.1, 78.7, and 40.8% *S. glauca*, *H. annuus*, and *A. rudis* seeds were recovered from the artificial seedbanks. In 2001, the

seed recovery was 43.7, 64.7 and 52.8% for *S. glauca*, *H. annuus*, and *A. rudis*, respectively.

4. Discussion

This study suggests that the use of composted swine manure is unlikely to increase weed seedbank abundance, to modify seed viability, or to affect weed seedling emergence. Several studies have reported that the composting process itself can reduce weed seed viability (Grundy et al., 1998; Tompkins et al., 1998; Eghball and Lesoing, 2000). The high temperature generated within the compost windrow in combination with its moisture content, microbial activity, and emission of various chemicals, including acetic acid and ammonia, decrease weed seed viability in composted material. Nevertheless, caution should be taken because minor addition of seeds from a species or biotypes not present in the weed flora could compromise future weed management options.

In 1998, a relatively large number of viable common waterhemp seeds were present in the compost. This compost was produced in a commercial farm where piles were not turned on a regular basis. We do not know if composting failed to provide the necessary conditions to reduce the viability of *A. rudis* seeds, or if compost was subsequently contaminated with seeds. However, in 2001, after three additional compost applications, few *A. rudis* seeds were detected in the seedbank of compost-amended sub-plots (Fig. 2). This result suggests that when weed management practices aimed at minimizing weed fecundity are implemented, occasional seed inputs occurring through compost amendments may not necessarily impact the number of seeds in the long term.

Although few viable *C. album* seeds were incorporated into the seedbank via compost application, soil cores obtained from the 2001 corn plots indicated a high abundance of viable and non-viable *C. album* seeds. In wheat plots, mowing was used to control weed escapes after crop harvest. For Canada thistle [*Cirsium arvense* (L.) Scop.], mowing can lead to enhanced reproductive efficiency due to an increase in the number of flowers (Kluth et al., 2003). It is not known whether a similar response occurs in *C. album*, but we believe that failure to control *C. album* re-growth and seed through mowing

in the wheat phase of the rotation could have contributed to the observed results.

Seedbank emergence plays an important role in weed population dynamics (Cousens and Mortimer, 1995). In this study, soil amendment had little effect on weed seedling emergence. Also, cumulative emergence patterns observed in this study are in agreement with those previously reported for first-year emergence in the Midwestern USA (Egley and Williams, 1990; Forcella et al., 1997; Hartzler et al., 1999; Buhler and Hartzler, 2001). In accordance with Forcella et al. (1997), weed seedling emergence varied among species and among years within a species.

In our study, between 31.3 and 59.2% of the seeds placed in the artificial seedbanks disappeared within 1 year. Agricultural weed seeds are subjected to several sources of mortality, including predation, disease, and fatal germination. These sources of mortality range from 21 to 99% of the total seed production and can have a significant impact on the number of seeds present in the soil (Lindquist et al., 1995; Cardina and Norquay, 1997; Buhler and Hartzler, 2001). Combining physical, cultural, and biological sources of weed seed mortality could have synergistic effects that will reduce dependence on non-farm chemical inputs as a tool to manage weeds (Hatcher and Melander, 2003).

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